[redacted]

Table 3-2: Maritime Industrial Waste Project – Maritime Business Participants

Name	Address	City
PILOT TEST – SHIPYARDS		
Todd Shipyard Corp.	1801 16th Ave. S.W.	Seattle
United Marine Shipbuilding Inc.	1441 N. Northlake Way	Seattle
Duwamish Shipyard Inc.	5658 West Marginal Way S.W.	Seattle
Foss Maritime	660 W. Ewing St.	Seattle
Marco Seattle Inc.	2300 W. Commodore Way	Seattle
Lake Union Drydock Co.	1515 Fairview Ave. E.	Seattle
PILOT TEST – BOATYARDS		
Fishermen's Boat Shop Inc.	1016 14th St.	Everett
Miller and Miller Boatyard	626 W. Ewing St.	Seattle
Port of Seattle, Shilshole	7001 Seaview Ave. N.W.	Seattle
Suldan's Boat Works Inc.	1341 S.W. State Highway 160	Port Orchard
Seaview East/West	4701 Shilshole Ave. N.W.	Seattle
West Bay Marine Center Inc.	2100 West Bay Dr.	Olympia
WASTEWATER CHARACTERIZATION		
Gig Harbor Marina	3117 Harborview Dr.	Gig Harbor
Kitsap Marina	1595 S.W. State Highway 160	Port Orchard
Northwest Yacht Repair	2046 Westlake Ave. N.	Seattle
Port of Port Townsend	P.O. Box 1180	Port Townsend
CSR	2401 N. Northlake Way	Seattle
Anacortes Yacht Service Inc.	2517 "T" Ave.	Anacortes
University Boat Service Inc.	3137 Fairview Ave. E.	Seattle
Devlin Boat Co.	2424 Gravelly Beach Loop N.W.	Olympia

4. Pilot Treatment Evaluation

The Maritime Industrial Waste Project pilot-tested 11 wastewater treatment systems at 12 boatyard and shipyard sites. Information about the maritime businesses and pilot-tested systems is provided below.

Description of Selected Yards and Treatment Systems

Shipyards

Todd Shipyard Corp.

Location	Harbor Island on Elliott Bay, Seattle
Operations	Ship construction, repair and maintenance Hydroblasting and pressure-washing Dry grit-blasting
Haul-outs	Three dry docks

Todd is a large shipyard capable of dry-docking ferries, commercial cruise liners and military vessels. Operations are carried out on floating dry docks and on land.

United Marine Shipbuilding Inc.

Location	Northwest end of Lake Union, Seattle
Operations	Ship construction, repair and maintenance Hydroblasting and pressure-washing Dry grit-blasting
Haul-outs	Four dry docks

United Marine Shipbuilding is a medium to large-sized shipyard that works predominantly on steel-hulled commercial vessels. Most operations are carried out on floating dry docks, with some repair shops and fabrication areas on land.

Duwamish Shipyard Inc.

Location	Lower end of Duwamish River, Seattle
Operations	Ship construction, repair and maintenance Pressure-washing Dry grit-blasting
Haul-outs	Two dry docks, one graving dock and one marine railway

Duwamish Shipyard is a medium to large-sized shipyard capable of working on a variety of ship types and sizes. Operations are carried out on floating dry docks and on the marine railway, the graving dock and in fabrication shops on land.

Foss Maritime

Location	Lake Union Ship Canal, Seattle
Operations	Ship construction, repair and maintenance Pressure-washing Dry grit-blasting
Haul-outs	Two dry docks

Foss Shipyard's major operation is to maintain its fleet of large tug boats and support vessels used in its marine transportation business. Operations are carried out on floating dry docks and on land.

Marco Seattle Inc.

Location	Lake Union Ship Canal, Seattle
Operations	Ship construction, repair and maintenance Pressure-washing Dry grit-blasting
Haul-outs	Two dry docks and one marine railway

Marco Seattle is a medium-sized shipyard that constructs and services many commercial fishing vessels. Operations are carried out on floating dry docks and on a marine railway on land.

Lake Union Drydock Co.

Location	Northeast side of Lake Union, Seattle
Operations	Ship construction, repair and maintenance Pressure-washing Dry grit-blasting
Haul-outs	Three dry docks and one crane

Lake Union Drydock is a medium-sized shipyard that works mostly on steel-hulled vessels. Operations are carried out on floating dry docks and on fixed docks set on piers over water.

Boatyards

Fishermen's Boat Shop Inc.

Location	Everett, Washington
Operations	Boat repair and maintenance Pressure-washing
Haul-outs	One marine railway

Fishermen's Boat Shop is a medium-sized boatyard that works on commercial fishing vessels and recreational boats.

Miller and Miller Boatyard

Location	Lake Union Ship Canal, Seattle
Operations	Boat repair and maintenance Hull-washing by hand
Haul-outs	One crane

Miller and Miller Boatyard is a small boatyard that works primarily on recreational boats.

Suldan's Boat Works Inc.

Location	Port Orchard, Washington
Operations	Boat repair and maintenance Pressure-washing
Haul-outs	Three marine railways

Suldan's Boat Works is a medium-sized boatyard that works on commercial and recreational boats.

Seaview East

Location	Lake Union Ship Canal, Seattle
Operations	Boat repair and maintenance Pressure-washing
Haul-outs	One travel lift

Seaview East is a large boatyard that repairs boats and provides facilities for customers to do their own repairs.

West Bay Marine Center Inc.

Location	Olympia, Washington
Operations	Boat repair and maintenance Pressure-washing
Haul-outs	One travel lift

West Bay Marine Center is a marina and boatyard that repairs boats and provides facilities for customers to do their own repairs.

Treatment System Descriptions

The Maritime Industrial Waste Project pilot-tested the following treatment systems.

Filtration – Mixed Media

This system is a commercially available continuous-flow mixed-media filter. The system is composed of a pressure vessel that holds the filter media and the piping and valves necessary for operation. The filter media is composed of layers of coal, coarse sand and fine sand. Untreated wastewater is pumped through the filter media, and the clarified water is discharged to the sanitary sewer. When the filter becomes plugged, a backwash cycle scrubs the collected contaminants from the filter media and into a backwash tank or sump.

Membrane Filtration – Ultrafiltration

The system's main components are a recirculating tank, membrane tubes and a process pump. Untreated wastewater is pumped to a 50-gallon recirculating tank. The wastewater is pumped through membrane tubes at a pressure of 40 to 60 pounds per square inch and back to the recirculating tank. A portion of the wastewater, called the permeate, passes through the membrane and is discharged. A level control maintains wastewater flow to the recirculating tank as needed. The volume of wastewater is reduced and concentrated in the recirculating tank. A concentration ratio of 20 to 40 times is ordinarily achievable.

Filtration – Media Precoat

This commercially available system operates in a continuous mode. The tested model has a treatment capacity of eight gallons per minute. The basic components of the system are a precoat filter unit, a body-feed injection system, piping, valves and a pump. The system operates by filtering wastewater through a thin layer of diatomaceous earth supported on fabric. When the filter begins to plug with contaminants, it is backwashed to remove the plugged media. New media is applied by running a slurry of fresh media through the filter. To avoid rapid plugging, a small amount of the filter media is introduced into the waste stream before filtering. This body feed, as it is called, makes the particulates more porous as they are collected on the filter media and maximizes filter capacity.

Settling and Filtration – Manufactured Mixed Media, System 1

The main components in this commercially available system are an oil/water separator and settling chamber, activated carbon filter and mixed-media filter. As wastewater is circulated through the system, particulates are removed by gravity in the settling chamber and by filtration in the mixed-media filter. The system comes with pumps, piping and controls. A wastewater sump or holding tank is required.

Settling and Filtration – Manufactured Mixed Media, System 2

The main components in this commercially available system are an oil/water separator and settling chamber, mixed-media filter, cartridge filter and activated carbon filter. As the wastewater is circulated through the system, particulates are removed by gravity in the settling chamber and by filtration in the mixed-media and cartridge filters. The system comes with pumps, piping and controls. A wastewater sump or holding tank is required.

Chemical Flocculation and Settling – Alum and Lime

This batch process can be carried out in a plastic 35-gallon garbage can. About 0.5 grams/liter of alum is added to wastewater in a batch treatment tank. The solution is mixed for several minutes. About 1 gram/liter of lime is then added to raise the pH to about 8. The pH is checked with pH paper, and more lime is added as needed. The solution is again mixed for several minutes and allowed to settle for 30 minutes. The clarified wastewater is then decanted and discharged to the sewer.

Chemical Flocculation and Settling – Iron and Lime

This yard-developed batch system involves the use of a 160-gallon plastic treatment tank and flocculating chemicals. About 0.5 grams/liter of iron chloride is added to wastewater contained in the treatment tank. The solution is mixed manually. About 1 gram/liter of lime is then added to raise the pH to about 8. The pH is checked with pH paper, and more lime is added as needed. About 50 mg/liter of anionic polymer is added, and the solution is mixed and allowed to settle for about 30 minutes. The clarified wastewater is then discharged to the sewer.

Chemical Flocculation and Settling – Proprietary Dry Chemical

This manufacturer-supplied system consists of a 700-gallon cone-bottom treatment and settling tank and an electric mixing unit. Wastewater is pumped into the tank, and about five pounds of proprietary dry chemical is added. The electric mixer is used to mix the solution for about 15 minutes. The mixer is turned off, and the flocculated wastewater settles for 30 minutes. The clarified wastewater is decanted from the tank. Batches are treated in the tank until the sludge needs to be removed from the bottom of the tank.

Chemical Flocculation – Cationic Polymer

The main components in this yard-developed, continuous treatment system are a chemical metering pump, mixing unit and settling tank. A flocculating polymer is metered into and mixed with wastewater as it flows into a settling tank. The polymer forms floc with wastewater particles, and the floc settles out in the settling chamber. Clarified wastewater is decanted from the settling tank and discharged to the sanitary sewer. The system is capable of treating 30 gallons per minute.

Dissolved-air Flotation – Continuous Alum Flocculation System

This commercially available system operates continuously with a treatment capacity of 24 gallons per minute. The basic components are chemical metering pumps, a chemical mixing unit, a dissolved-air generator, a clarifier tank and a rotating sludge skimmer. Alum and a polymer are used to flocculate wastewater particles, and dissolved air is introduced to a clarifier to float the floc. The floating sludge is removed continuously by a rotating skimmer. Clarified wastewater is removed from the clarifier and discharged to the sanitary sewer.

Induced-air Flotation – Alum Batch System

The main components in this commercially available system are a reactor/flotation tank, induced-air supply pump and solids-collection filter tray. Alum, lime and a polymer are added to achieve flocculation. Air is introduced by recirculating the solution through a pump, which draws in air and mixes it with the solution. The pump is then shut off, and the floc is allowed to rise with attached air bubbles. The clear solution and floating flocs are drained to a filter below the tank, and the filtered water is discharged to the sanitary sewer.

Pilot-test Results

Performance test data for each system is summarized in Appendix E, pages 39-49. Table 4-1 presents an overall evaluation of the treatment systems tested.

All the systems tested were determined capable of treating pressure-washing wastewater to levels sufficient for meeting Metro and boatyard NPDES sanitary sewer discharge limits. None of the systems were able to meet NPDES requirements for discharge to receiving waters. These findings were not totally unexpected since the systems were designed to treat wastewater to that quality.

Operational Advantages and Disadvantages

The treatment systems can be divided into two main groups: filtration processes and chemical processes. The filtration processes use various types of filtering media or porous surfaces to separate suspended solids from the wastewater. Chemical processes use a chemical agent such as alum, iron or polymer to coagulate small wastewater particles into larger combined clumps of particles called flocs. The flocs are then readily separated from the wastewater either by settling or flotation.

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Table 4-1: Evaluation of Pressure-washing Wastewater Treatment Systems Equipment, Based on Pilot-testing

Treatment System	Operation Mode	Capable of Meeting Limits		Advantages	Disadvantages	Comments
		Sewers	NPDES			
FILTRATION PROCESSES						
Mixed-media filtration	Continuous	Yes	No	Effective treatment for solids removal. Simple operation.	Plugs rapidly without prior settling or flocculation. Filter cleaning cycle can require large amounts of water.	Most useful as a polish filter or for treating wastewater with low solids.
Ultrafiltration	Continuous	Yes	No	Removes nearly 100 percent of wastewater solids. Can treat raw wastewater without pretreatment.	Paying for more treatment than might be needed. Membrane replacement costs can be high.	Need to test system over a period to determine life expectancy of membranes.
Precoat (diatomaceous earth)	Continuous	Yes	No	Designed and effective for solids removal. Cleaning cycle, using small volume of water, is short.	Frequent cleaning cycles may occur without some pretreatment.	Must adjust media type and grade to guarantee effective treatment.
Pre-engineered filtration systems (packaged – two tested)	Continuous	Yes	No	Systems come as a complete package. Established operation and maintenance procedures. May be available in "water recycle" models.	Systems may not have sufficient primary settling. Systems may include more treatment steps than necessary. Requires control for biological growth in equipment.	Needs a trial testing period on-site. Water recycle models need to be tested under field conditions.
CHEMICAL PROCESSES						
Flocculation – alum and lime	Batch	Yes	No	Effective – simple equipment and operation. Consistent over range of wastewater strengths.	Requires some chemical handling and storage. Requires addition of lime for pH control.	Settling step is necessary after flocculation. Filter can be used to polish clarified water.
Flocculation – iron and lime	Batch	Yes	No	Effective – simple equipment and operation. Consistent over range of wastewater strengths.	Requires some chemical handling and storage. Requires addition of lime for pH control.	Settling step is necessary after flocculation. Filter can be used to polish clarified water.
Flocculation – proprietary dry chemical	Batch	Yes	No	Effective – simple equipment and operation. One-step application of dry chemical.	Requires some chemical handling and storage. Filter can be used to polish clarified water.	Settling step is necessary after flocculation.
Flocculation – cationic polymer	Continuous	Yes	No	Effective treatment for solids removal. Only one chemical required.	Requires pumps and controls for continuous operation.	Could be used in a batch treatment process.
Flotation – dissolved-air	Continuous	Yes	No	Effective flocculation of solids by using alum. Can treat for oil and grease.	Requires pumps and controls for continuous operation.	Most applicable to large operations.
Flotation – induced-air	Batch	Yes	No	Effective flocculation of solids by using alum. Can treat for oil and grease.	Flotation may be inconsistent.	Needs a trial testing period on-site.

The advantage of chemical treatment is that the wastewater solids are converted to flocs that quickly settle or float from solution. Since filtration is not mandatory, there are no filters to maintain or replace. Chemical treatment is also easily modified to handle small and large wastewater volumes. Miller and Miller Boatyard, for example, effectively treats wastewater in batches with alum and lime in 35-gallon containers. Foss Maritime successfully tested a similar treatment system using a proprietary coagulant and a 700-gallon tank. Large-volume generators can also choose a continuous chemical treatment system, such as the diffused-air flotation system tested at Duwamish Shipyard.

Chemical treatment has the disadvantage of requiring some operator skill in measuring, mixing and handling chemicals. The treatment processes using alum, for example, require weighing out alum in proportion to the volume of wastewater present and adding lime to adjust the pH of solution. These processes can be operated with automatic metering devices, but their costs rise substantially.

Filtration systems have the advantage of being mechanical, using tanks, pumps and filters and not using chemicals that require handling, mixing or metering. Pressure-washing wastewater, however, causes filters to plug rapidly, resulting in frequent maintenance that requires cleaning or replacing filters. The tested systems used several strategies to reduce this frequent maintenance. The ultrafiltration process, for example, recirculates wastewater over the surface of a porous membrane filter with pores sized much smaller than the particles in solution. This filter process allows treated water to pass across the filter while the suspended solids stay in solution. Solids, therefore, do not build up on the filter surface. Over time, however, solid particles will eventually accumulate inside the membrane filter, and the filter must be replaced. The filter can also deteriorate from gradual erosion and need to be replaced.

Filter systems that capture and hold solids on their surface, such as cartridge and bag filters or inside a media matrix, such as sand media or multimedia filters, will plug rapidly when treating pressure-washing wastewater. Media filters can be cleaned, but require time and large amounts of water to backwash the media. Precoat filtration minimizes this problem by using a temporary media on a fixed porous surface. When the filter becomes plugged, the temporary media is removed, and a layer of new media is applied to the fixed surface.

All filtering processes benefit from the partial removal of solids through settling before filtration. Settling before filtration prolongs the life of filters or extends the duration of the treatment cycle before cleaning becomes necessary. A settling step is required for cartridge, bag and multimedia filters to prevent excessive plugging. Chemical coagulants can be used in this settling step to enhance and accelerate the settling process.

Collection System Requirements

At present, most boatyards and many shipyards do not have fully operational collection systems for capturing and containing wastewater generated during pressure-washing. Several boatyards and shipyards visited during the project had already implemented collection systems or were in the process of doing so. With the exception of a sloped concrete pad similar to those used at truck washing facilities, there are no established collection system designs.

The design of collection systems for pressure-washing operations is dependent on the type of haul-out used. The deck and side walls of most dry docks, for example, already provide the basic containment structure required. In contrast, most marine railways have no containment structures, are usually sloped toward the water and are periodically submerged and exposed in tidal areas.

The project identified the following components as essential to an effective wastewater collection system:

- Water impervious deck, pad or other haul-out surface. The surface should slope to a collection sump or trench. Dry docks may be temporarily sloped by regulating dry dock ballasts.
- Adequate wash area to contain all direct and deflected water spray from the wash operation.
- Containment walls, berms or raised surfaces that allow wastewater to be collected during washing within the containment area.
- A collection sump, trench or depressed surface area located within the containment area. The sump is used to accommodate a sump pump and to store wastewater temporarily.

Collection System Designs

During the project, the following collection system designs were developed, based on existing or planned systems. The designs were categorized according to haul-out types.

Cranes, Travel Lifts and Trailer Hauls

These haul-out systems move boats to upland areas where a permanent or portable system can be constructed or set up.

Figure 4-1 shows a fixed-pad collection system design similar to those used for truck pressure-washing facilities.

Figure 4-2 shows a portable collection system design that uses a heavy tarpaulin to contain wash water. This design is based on a system developed at Miller and Miller Boatyard.

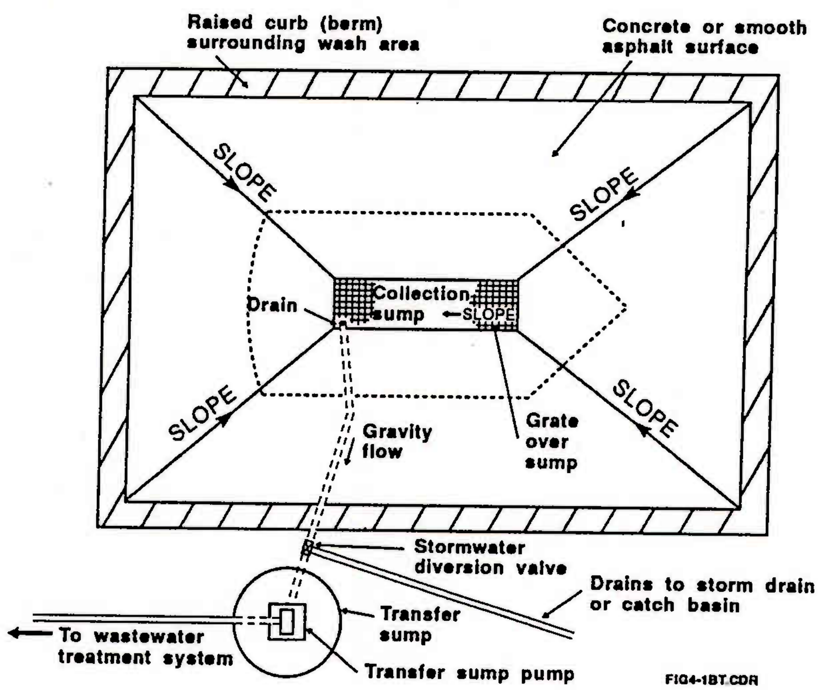

Figure 4-1: Fixed-pad Collection System

Dry Docks

Dry docks can be temporarily sloped toward one end or one corner to create a surface that promotes the flow of wastewater to a collection area. For some dry docks the deck surface has to be modified to allow for an unobstructed flow.

Figure 4-3 shows a dry dock collection system design based on one developed at United Marine Shipbuilding.

Marine Railways

Marine railways are fixed-position haul-outs where washing usually occurs on a slope running to the shoreline. To successfully collect wastewater, a boat or ship must be raised to solid ground above the water line.

Figure 4-4 show a diagonal-berm collection system design based on one developed by Gig Harbor Marina.

Figure 4-5 shows a trench collection system design based on one developed at Suldan's Boat Works.

Treatment Solids-handling Requirements

Solids contaminated with heavy metals in the treatment process must be disposed of within federal, state and local guidelines.

The project identified the following disposal options as the most effective for boatyards and shipyards:

- Contracting with a waste disposal company to haul away raw or dewatered sludge.
- Arranging for sludge disposal at a landfill. This option requires checking with Ecology and the local health department to determine what tests are required before the sludge can be taken to a landfill.

Currently, a Toxicity Characteristic Leaching Procedure (TCLP) test is required by health departments for assessing whether the sludge is hazardous or can be taken to local landfills. In

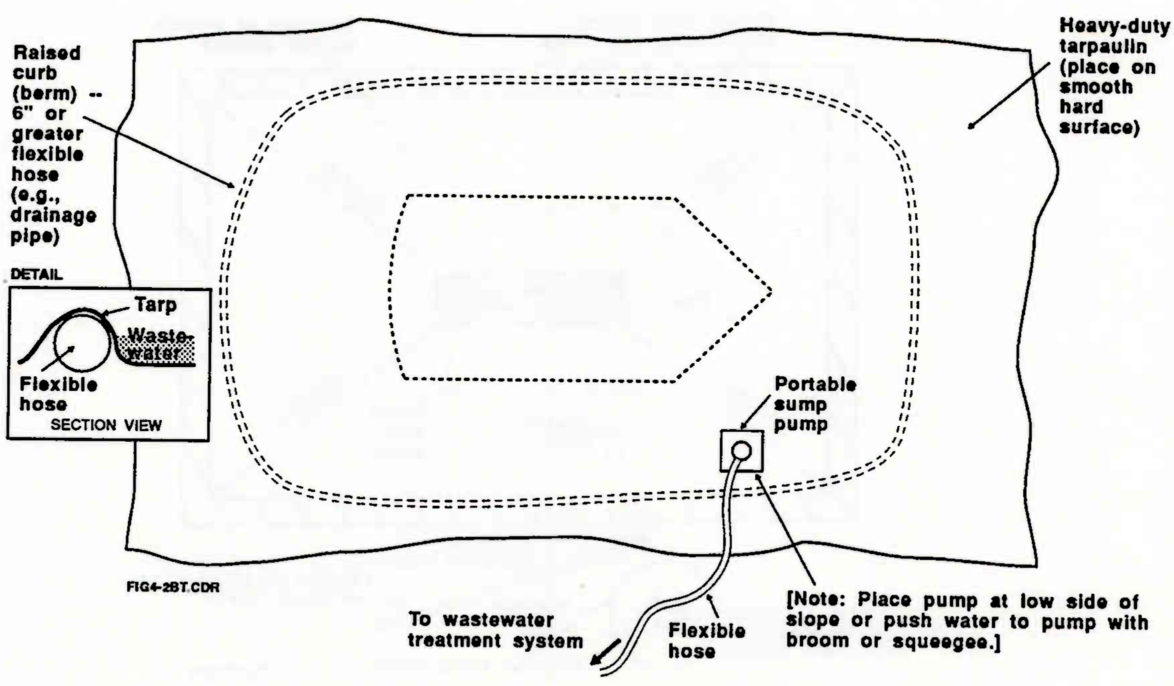

Figure 4-2: Portable Collection System

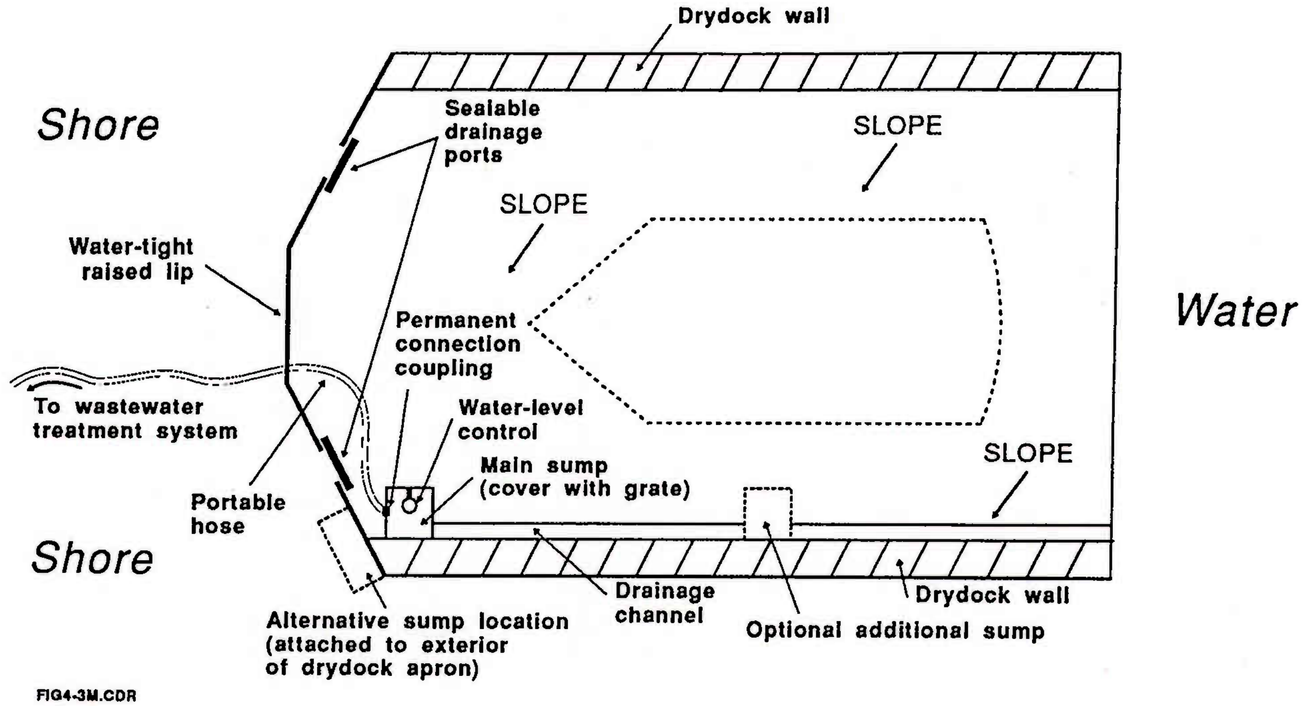

Figure 4-3: Dry Dock Collection System

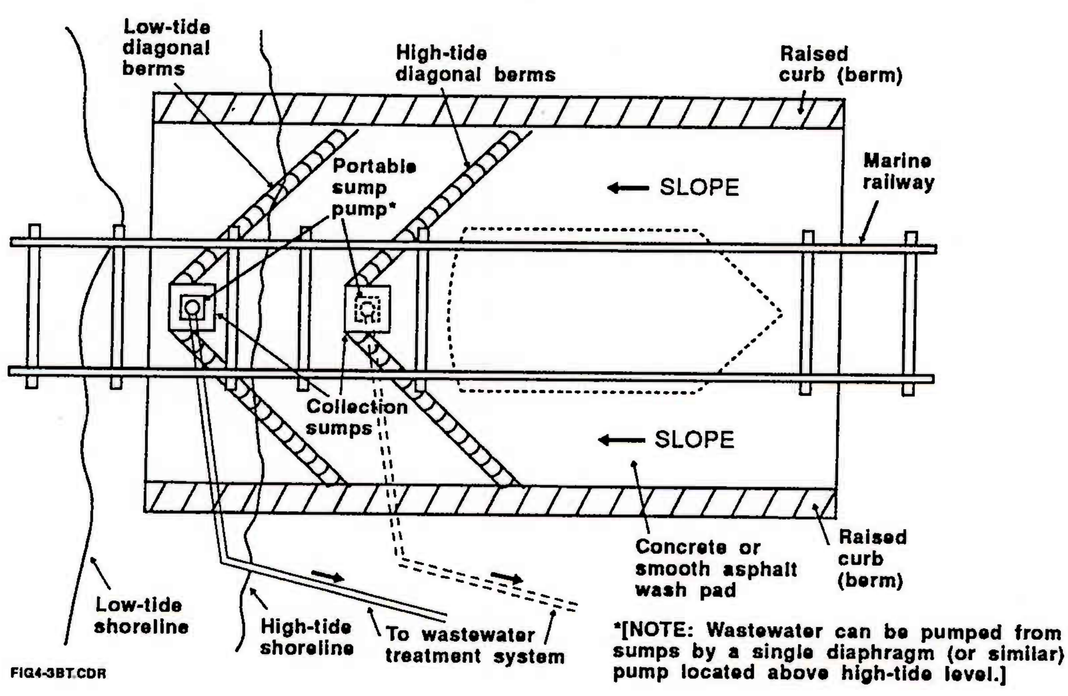

Figure 4-4: Diagonal Berm Collection System for Marine Railways

some cases, Ecology may require further tests, such as bioassays, to determine if the sludge is hazardous waste. Because of uncertainty over when Ecology may require tests, businesses were advised to contact Ecology before making arrangements for disposal.

Two TCLP tests were performed on shipyard sludge generated in treatment tests. In both cases, sludge samples passed the TCLP test. Because pressure-washing wastewater treatment sludges can be expected to be similar in content, sludges from other shipyards and boatyards not tested should have a high probability of passing the TCLP test.

Since the volume of solids generated at most boatyards is not great – on the order of one or two 55-gallon drums a year – the cost of disposing of these materials, if they are hazardous, would not be a heavy financial burden. If the boatyard can dewater or dry its sludge, then the boatyard can reduce the volume of material and cost of disposal. Boatyards or shipyards may want to handle their wastewater sludge as hazardous waste, whether tests confirm this or not. By handling sludge as a hazardous waste, a maritime business avoids some of the costs associated with testing sludge for landfill disposal. In addition, by disposing of sludge as a hazardous waste, the business has the added assurance that the sludge is being disposed of in a more environmentally safe way than disposal at a landfill.

System Designs and Costs

The project identified the following factors as important in determining the suitability of a particular treatment system for a boatyard or shipyard:

- volume of wastewater generated
- level of complexity of the treatment system, whether automatic or labor intensive
- level of labor and expertise available at the boatyard or shipyard
- capital and maintenance costs of the equipment.

Because of the significant difference in volume of wastewater generated at shipyards and

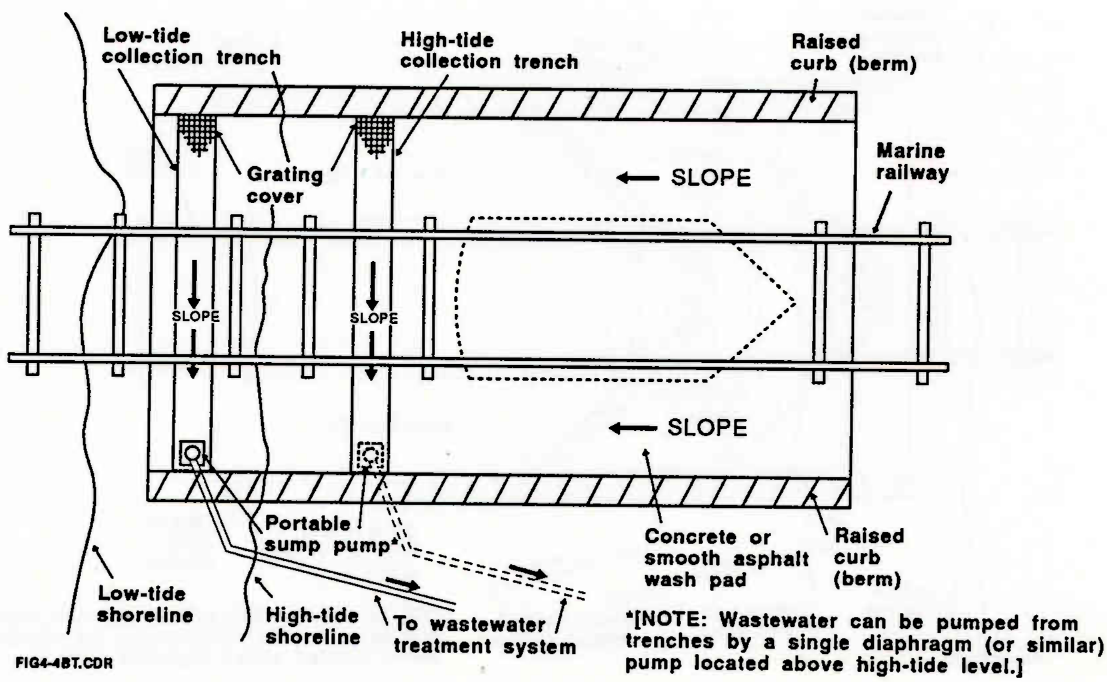

Figure 4-5: Trench Collection System for Marine Railways

boatyards, treatment systems have to be adjusted accordingly. Treating wastewater in batches, for example, is much more practical for a small boatyard that generates 100 gallons a day than for a shipyard that generates 10,000 gallons a day. In this case, a treatment system that treats continuously would be more appropriate.

The generic design for a batch treatment system, shown in Figure 4-6, was developed as an appropriate treatment system that can be constructed by small boatyards generating volumes of wastewater less than 100 gallons per boat wash. This design incorporates chemical flocculation and settling.

The following is a breakdown of estimated costs for this small system:

Heavy duty tarpaulin	$500
Treatment barrels (3 @ $20 each)	60
Bermed and covered treatment area	500
Pump, hoses and fittings	500
	$1,560

For this system, whenever possible, a boatyard should install a permanent wastewater collection area, or bermed wash pad, in place of a portable collection system. This system can also be increased in size to handle higher volumes and can be designed and installed entirely or partially by equipment suppliers or consulting engineers.

For large boatyards and shipyards, a typical system design shown in Figure 4-7, was developed to handle the larger volumes of wastewater. The following is a breakdown of estimated costs, which can vary according to type and capacity of the equipment:

Induced-air or dissolved-air flotation	$20,000-$50,000
Ultrafiltration	$15,000-$30,000
Settling/multimedia filtration (packaged system)	$5,000-$30,000
Flocculation/settling – 1,000-gallon batch	$3,000-$5,000
Precoat filtration	$10,000-$20,000

Additional equipment and site-preparation costs are indicated below:

Bermed treatment area	$2,000-$5,000

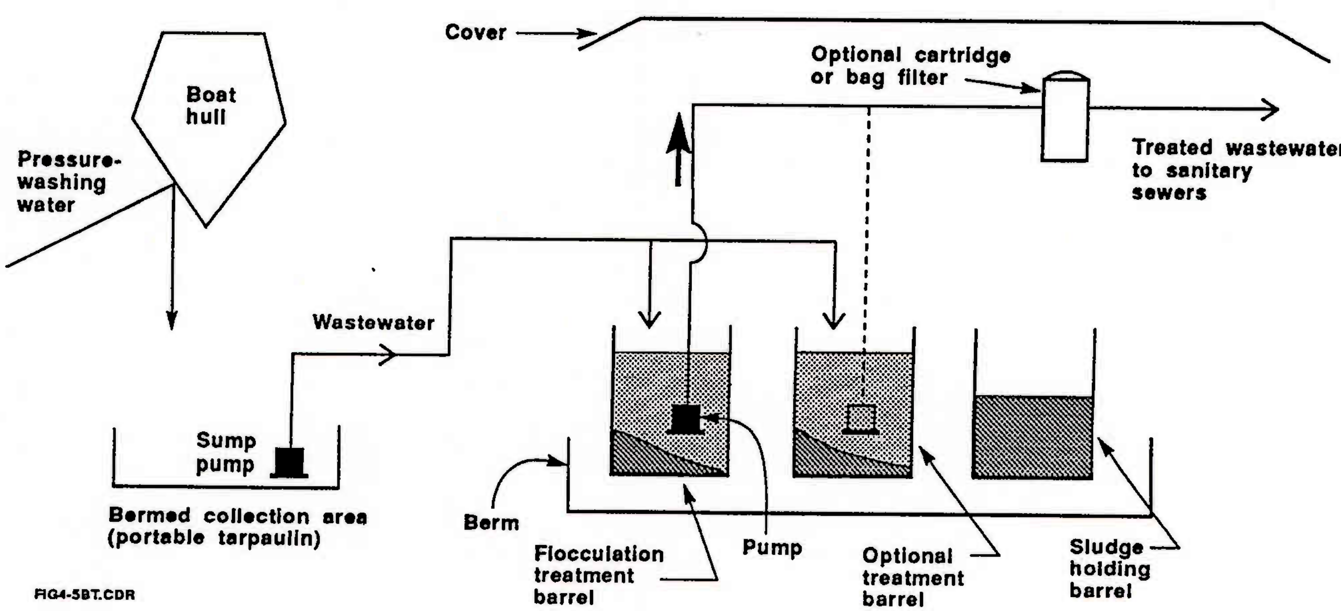

Figure 4-6: Flow Diagram of Example Treatment System for Small Boatyards

Holding tank – 1,000-5,000 gallons	$1,000-$10,000
Filter press	$7,000-$15,000
Piping and electrical	System dependent

These designs, which were developed to address the basic regulatory and engineering requirements necessary, are intended to be used as guidelines. The designs should be modified, as necessary, to accommodate particular boatyard or shipyard conditions and wastewater volumes.

Wastewater Treatment Guidelines for Shipyards and Boatyards

Two wastewater treatment guideline documents were prepared during the project to help shipyard and boatyard operators comply with NPDES and sanitary sewer discharge permits. The documents focus on the selection of discharge routes and the implementation of wastewater collection and treatment systems. The guidelines also discuss what regulations and permits apply to maritime facilities, how to handle treatment solids, how to prepare engineering reports and how to implement best management practices (BMPs). The guideline documents are included in appendices E and F.

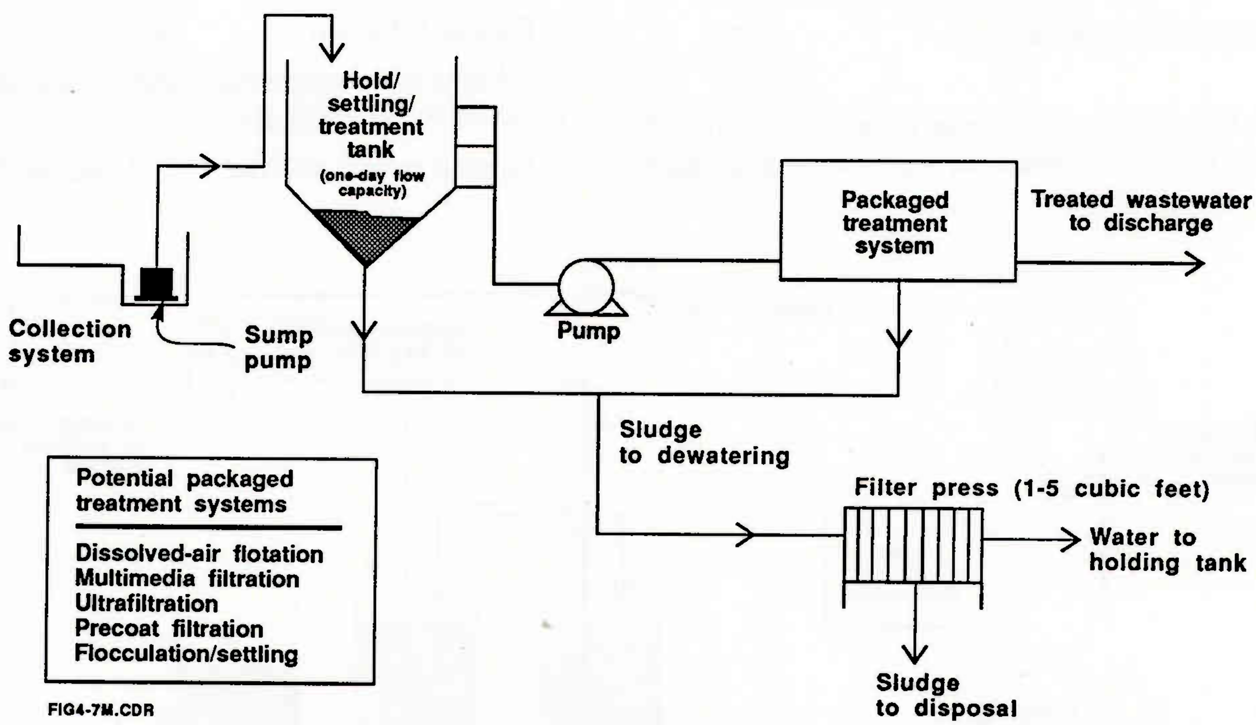

Figure 4-7: Flow Diagram of Example Shipyard Treatment System

5. Other Pollutant Sources And Mitigation Measures

Stormwater

Unless preventive measures are taken, stormwater runoff from boatyards and shipyards can be readily contaminated by dust sandings and scrapings from hull-painting preparation. Because the solid debris is generated from bottom paint removal, the contamination is qualitatively similar to that in pressure-washing wastewater. The quantity of contamination is dependent on the size of the area worked on, the type of work surface and the degree to which source controls, such as best management practices (BMPs), have been implemented. BMPs, such as tarping, sweeping and vacuuming, provide the means for making significant reductions in the contamination of stormwater.

Hazardous Materials

Hazardous substances, such as solvents, paints, fuels and various other chemicals used in boat repair or fabrication, need to be prevented from entering storm drains and sanitary sewers or being released to receiving waters. Many boatyards and shipyards conduct operations in uncovered yard areas that have no berms or walls for containment. In these areas, spills and leaks can find their way to sewers or receiving waters. BMPs that provide for secure storage and management of hazardous materials and wastes can reduce potential contamination to stormwater.

Bilge and Ballast Water Treatment

The project pilot-tested the treatment of bilge water at a shipyard site and a marina/boatyard site. A coalescing-type oil/water separator and a diffused-air flotation system were tested. Although treatment for the reduction of oil in bilge water was effective in both cases, other problems with bilge water treatment became evident during testing. Because there is often no control on substances such as fuels, cleaning solvents and detergents entering bilges, bilge water can show wide variations in its characteristics and its treatability. In addition, the use or recommendation of a single treatment process or system is problematic. Simple one-step oil/water separation is consistently effective only if bilge water is not emulsified and does not contain regulated organics, such as chlorinated solvents. Bilge water treatment may require several treatment stages, including breaking down the emulsion and treating it for regulated organic compounds.

Based on these findings, the project developed the following guidelines:

- Boatyards accepting bilge water from vessels they service are advised to collect and hold the wastewater in a secure and bermed tank. A waste disposal company can be contracted for haul-away and treatment.
- Shipyards may choose to test and treat bilge water on a case-by-case basis. They have three options:
  - To treat and discharge contaminated bilge water to the sanitary sewers if it meets discharge limits and the oil in the bilge water is not emulsified or contaminated with heavy metals, fuels or solvents. To accomplish this, the shipyard must be able to control the cleaning agents used in holds and the engine room.
  - To treat and discharge contaminated bilge water to receiving waters only if treatment equipment is capable of removing oil and grease, heavy metals and regulated organic compounds to meet NPDES limits. Treatment equipment for this option may be expensive and difficult to operate.

- To contract with a waste disposal company to haul away bilge water, particularly if there is uncertainty over possible fuel or organic contamination.

These recommendations also apply to the handling and treatment of ballast water. Ballast water may be uncontaminated and suitable for direct discharge to a receiving water or it may need to be hauled away by a waste disposal company because of contamination. As with bilge water, boatyards and shipyards need to handle ballast water on a case-by-case basis and observe all the applicable discharge limits for receiving waters or sanitary sewers.

Implementation of BMPs

Shipyards and boatyards visited during the course of the Maritime Industrial Waste Project were found to have varying degrees of awareness of BMPs and their implementation. Because of previous contacts with environmental agencies, shipyards were generally more knowledgeable of BMPs than boatyards. There were, however, some better informed managers at several boatyard facilities that had implemented BMPs. Several boatyard owners groups and trade organizations around Puget Sound have been informing their members of the need for and benefits of implementing BMPs at their facilities. On the other hand, the project learned of less informed and sometimes unscrupulous boatyard owners or managers who operate their facilities without routine yard-cleaning, spill prevention plans or pollution prevention practices.

The importance of following BMPs cannot be underestimated. When compared to the potential costs of treating large volumes of wastewater for low levels of contaminants, controlling sources of contamination through housecleaning and other preventive measures may be significantly more cost-effective than treatment. Recognizing the effectiveness of BMPs as it developed the Boatyard General NPDES Permit, Ecology required BMPs for controlling contaminants in stormwater.

6. Model Basinwide Implementation Plan For Wastewater Pretreatment

Model Plan Objective

The main objective of the model basinwide implementation plan is to facilitate the implementation of pollution reduction in the Puget Sound basin through wastewater treatment and to recommend that treated wastewater be discharged to sanitary sewers when practical and feasible.

The plan objective is congruent with the overall goal of the Maritime Industrial Waste Project and of Ecology's general boatyard and individual NPDES programs for boatyards and shipyards. The implementation plan stresses the role of sanitary sewers in providing a practical discharge option for boatyards and shipyards. At present, wastewater pretreatment required to meet sanitary sewer discharge limits is achievable and cost-effective. Wastewater treatment required to meet NPDES receiving water discharge limits has greater technical uncertainties than sewer discharge pretreatment and involves substantially higher treatment costs. Zero-discharge alternatives may be practical for some small-volume dischargers, but the technology still requires more testing and in-field use to establish its performance record.

Basinwide implementation of wastewater pretreatment for sanitary sewer discharges is viewed as an attainable and cost-effective plan that is consistent with the goals of environmental regulation and protection.

Plan Elements

The plan is intended to compliment and augment the objectives of Ecology's NPDES program. The process of regulating wastewater discharges and other pollutant sources at boatyards and shipyards can be represented as occurring in three phases.

Phase 1

In 1990 and 1991, with advice from the maritime industry and other public agency representatives, Ecology develops industry-specific compliance regulations for pollutant discharges and incorporates them into individual or general NPDES permits.

Phase 2

In 1991, Ecology and Metro research and establish appropriate treatment methods for wastewater and discharge routes. In addition, public agencies and the maritime industry help establish industry-specific BMPs such as housekeeping procedures, spill prevention plans and hazardous waste storage and disposal plans.

Phase 3

In 1992 and 1993, Ecology issues NPDES permits to boatyards and shipyards. Ecology and Metro provide information and technical assistance to boatyards and shipyards in the Puget Sound area for establishing compliance with NPDES permits and permits from municipal sewerage agencies. Metro informs other sewer Puget Sound sewage systems of new boatyard and shipyard regulations. Boatyards and shipyards implement pressure-washing wastewater pretreatment for discharges to sewers, where available.

The main activity of the implementation plan occurs in phase three when boatyards and shipyards begin applying for NPDES and sewer permits and purchasing and installing wastewater treatment equipment. At that time:

- Metro will develop and issue wastewater treatment guidelines to boatyards and shipyards in the Puget Sound area. The guidelines will include specific information on the applicability, performance and cost of available treatment technologies that can be used for sewer discharge pretreatment.

- Metro will provide other Puget Sound sewerage agencies with the wastewater treatment guidelines and coordinate an exchange of information through written documents, verbal communications or meetings between Metro, sewerage agencies and Ecology.
- Metro will inform and coordinate with sewerage agencies in the counties surrounding Puget Sound to encourage pretreatment and discharge of boatyard and shipyard wastewater to sewage systems.
- Metro will serve as the lead agency for disseminating maritime industry pretreatment information to other Puget Sound sewerage agencies.

Issues for Sewerage Agencies

Sewerage agencies that currently manage industrial pretreatment programs have the organization and authority to regulate new discharges from boatyards and shipyards. The agencies are familiar with industrial discharge limits, potential impacts to treatment plants and regulations governing the treatment process. On the other hand, sewerage agencies without industrial pretreatment programs, called non-delegated sewerage agencies, do not have the authority or organization within their agency to regulate industrial wastewater discharges to their treatment plants. The General Boatyard NPDES Permit, however, will authorize boatyards to discharge pretreated pressure-washing wastewater to these non-delegated sewerage agencies if the boatyard discharges are in compliance with the permitted limits. In these situations, Ecology acts as the regulator of the pretreatment program for the non-delegated sewerage agencies so they can accept industrial wastewater to their systems. The non-delegated sewerage agencies, however, are not obligated to accept these discharges at their treatment plants.

Because of inexperience with industrial discharges to the sewers, non-delegated sewerage agencies have several concerns about the impact of industrial discharges on treatment plants and how the discharge is regulated and enforced. These concerns include:

- Impact of added wastewater volumes to treatment plants
- Impact of industrial discharges on biological treatment processes
- Impact of industrial discharges on sludge quality
- How stormwater is managed and restricted from sewer discharges
- How the maritime industry is monitored and regulated for compliance to discharge limits.

The general NPDES permit specifies and Ecology enforces the discharge concentration limits for pressure-washing wastewater discharged from boatyards to non-delegated sewerage agencies. Monitoring and reporting requirements are specified in the NPDES permit and enforced by Ecology, but the sewerage agency can choose to require more frequent wastewater monitoring. Ecology also reviews and approves engineering designs for wastewater collection and treatment before boatyards commence discharging to sanitary sewers or state waters. Stormwater management is also considered in this review.

An example of the potential impact to a sewerage agency that accepts treated pressure-washing discharges from a boatyard is shown in Tables 6-1 and 6-2. The tables show the estimated concentrations of copper, lead and zinc that might be produced in treatment plant influent and sludge. The example uses September 1991 data from the Carkeek Treatment Plant operated by Metro in Seattle. The Carkeek Plant is a primary sewage treatment plant with an

Table 6-1: Estimated Impact to Treatment Plant Effluent From One Boat Wash, Based on September 1991 Carkeek Treatment Plant Data [1]

Metal	Existing Influent Concentration (ppm)	Estimated Concentration Increase (ppm)	Influent Concentration After One Boat Wash (ppm)
Copper	0.058	0.004	0.062
Lead	0.03	0.002	0.032
Zinc	0.25	0.001	0.26

[1] Concentrations are based on 2.3 million gallons of treatment plant flow per day, with 75 gallons of treated water being discharged in 30 minutes at NPDES sewer limits of 2.4 ppm copper, 1.2 ppm lead and 3.3 ppm zinc.

Table 6-2: Estimated Impact to Treatment Plant Sludge From One Boat Wash, Based on September 1991 Carkeek Treatment Plant Data [1]

Metal	Existing Sludge Concentration (ppm)	Estimated Concentration Increase (ppm)	Sludge Concentration After One Boat Wash (ppm)
Copper	7.1	0.03	7.13
Lead	2.0	0.02	2.02
Zinc	17	0.04	17.04

[1] Concentrations are based on 6,000 gallons of sludge produced per day, with sludge composition at 3.5 percent solids and NPDES limit concentrations of metals accumulating in the sludge.

average flow rate of about 2.5 million gallons per day.

The metal concentration estimates indicate that impacts per boatyard to sewerage agencies with Carkeek's capacity are predicted to be very slight, if measurable at all. Smaller treatment plants may experience some increase in the level of metals measured in influent wastewater or sludge, but any operational or regulatory impacts of significance appear remote. To validate these estimates and to make similar calculations as those shown in Tables 6-1 and 6-2, sewerage agencies may want to use their treatment plant's capacity and the number of boat washes they expect.

Wastewater volumes generated from pressure-washing at a boatyard are estimated to be about 75 gallons per vessel on average. Since boatyards rarely wash more than 5 to 10 boats in a single day, the wastewater volume discharged to a treatment plant is likely to reach a maximum of 375 to 750 gallons per day from each boatyard. This volume is not expected to adversely impact the operation of most treatment plants.

Implementation Schedule

Phase 1 and 2 activities – developing the General NPDES Boatyard Permit and identifying appropriate pollution control measures – were undertaken in 1990 and 1991. Issuance of the general boatyard permit is currently scheduled for Spring 1992.

Before the boatyard general permit is issued, Metro and Ecology will provide wastewater treatment guidelines to the maritime industry and sewerage agencies in the Puget Sound area. Metro will also direct efforts toward coordinating and exchanging information with other sewerage agencies that may have concerns about wastewater discharges to their systems.

The final phase effort – implementation of wastewater treatment at boatyards and shipyards in the Puget Sound area – will take place through 1992 and into 1993, if necessary.

Education of and dissemination of information to the maritime industry will also take place in 1992 and continue into 1993 as required.

Pollutant-loading Reductions

The project estimated the total annual mass of copper, lead and zinc generated by a typical boatyard or shipyard from pressure-washing operations. This calculation was based on average concentrations of copper, lead and zinc found in the wastewater characterization. The volume of generated wastewater was calculated from project field data.

The calculations were based on the following information:

	Boatyards	Shipyards
Average number of vessels washed annually	100	75
Average gallons of wastewater generated per pressure-washed vessel	75	1,625
Total gallons of wastewater generated per year	7,500	122,000
Total pounds of metals generated annually per facility		
Copper	3.4	12.6
Lead	0.1	0.3
Zinc	0.4	6.7

Using the 1988 census figures cited earlier approximately 126 boatyards, 74 marinas and 35 shipyards are engaged in vessel repair operations in the 12 counties surrounding Puget Sound. Assuming that 200 boatyards and boatyard/marinas and 35 shipyards in the Puget Sound area conduct pressure-washing operations, the breakdown of the total loading of copper, lead and zinc in pounds to Puget Sound waters from all maritime facilities is as follows:

	Boatyards	Shipyards
Copper	686	441
Lead	21	12
Zinc	75	233

As expected the average shipyard generates more contaminants than the average boatyard. As shown above, however, it is estimated that boatyards as a group generate 1.5 times more copper and 2 times more lead than shipyards as a group do. Because of their greater use of paints containing zinc, shipyards generate 3 times more zinc than boatyards.

As shown in Figure 6-1, contribution of copper to Puget Sound waters from pressure-washing at boatyards and shipyards is relatively low compared with other major sources of copper. Pressure-washing contributes about 1,127 pounds of copper whereas municipal sewerage agencies and industry reportedly contribute about 57,000 and 55,000 pounds of copper respectively (Paulson et al., 1988). This comparison does not take into consideration that contaminants in pressure-washing water do not readily disperse into deeper waters. Pressure-washing contaminants are mostly particulate and remain localized in sediments near a maritime facility. The proximity of these facilities to shorelines and shallow waters could increase water-column concentration levels in those areas. Elevated contaminant concentration in these areas is of concern because of the ecological sensitivity of shallow-water shoreline environments. Shallow water and estuaries are known to be important habitats for food organisms and shellfish. In many cases, they are migratory routes for fingerling salmon.

Potential reduction in the loading of contaminants can be estimated from the results of the wastewater treatment pilot tests. An average treatment efficiency was calculated for the 11 treatment systems tested. Treatment efficiencies were found to be 94 percent for copper, 82 percent for lead and 89 percent for zinc. These estimates are conservative to take into account some inefficiency in pilot-tests. These levels of treatment are achievable with currently available treatment systems. The treatment is sufficient to allow treated wastewater to be discharged to sanitary sewers in most cases, but it is not sufficient to allow treated wastewater to be discharged to receiving waters under current NPDES limits.

Based on the treatment efficiencies and an assumption that 100-percent of wastewater from maritime facilities will be treated at the efficiencies found in treatment systems tested, the total annual mass-loading reductions to Puget Sound would be 1,060 pounds of copper, 27 pounds of lead and 274 pounds of zinc.

Cost of Basinwide Implementation

There are two main financial elements that need to be considered in the basinwide implementation plan: agency research and administrative costs, and maritime labor and equipment costs.

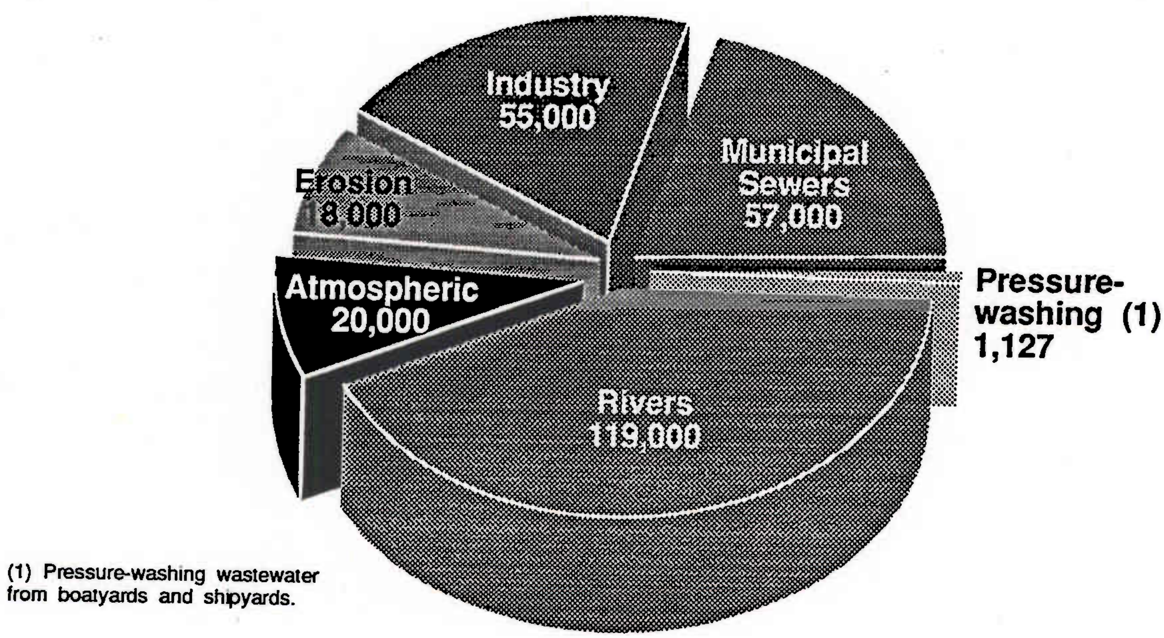

Figure 6-1: Estimated Total Annual Copper Loading to Puget Sound – Pounds of Copper Contributed by Source
(Does not consider water advection into or out of Puget Sound basin.)

To estimate administrative costs, the project assumed that EPA, Ecology and Metro and other sewerage agencies would need to hire one full-time employee each over the next two years for a total of three full-time employees. At an estimated $50,000 per employee, total administrative costs would be $150,000.

The cost of implementing wastewater treatment, which includes upgrading facilities and installing collection and treatment systems, is estimated to average $15,000 for each boatyard (from a range of $5,000 to $25,000) and $65,000 for each shipyard (from a range of $40,000 to $90,000). These estimates are based on the costs of the currently implemented collection and treatment systems and the costs of equivalent systems. Facility upgrading includes paving yard work areas, installing stormwater catch basins and constructing pressure-washing wastewater collection systems.

If the estimated 200 boatyards and boatyard/marinas and 35 shipyards around Puget Sound implement wastewater treatment, then the basinwide cost for treatment, based on average costs, would be $3 million for boatyards and $2.3 million for shipyards.

Combining both administrative and treatment system costs, the total basinwide implementation for 1992 and 1993 would cost $5.4 million.

Resources for Technical Assistance

The guideline documents for boatyards and shipyards in appendices E and F contain resources for technical assistance. Those resources may be found on page 31-33 in Appendix E for shipyards and page 27-29 in Appendix F for boatyards.

7. Conclusions And Recommendations

Conclusions

Wastewater Characterization

- Pressure-washing wastewater, which includes wastewater produced by pressure-washing, hydroblasting and hand-washing of boat hulls painted with antifouling paints, was determined to exceed NPDES limits and sanitary sewer limits for copper consistently. Lead and zinc concentrations were found to exceed NPDES limits consistently and exceed sanitary sewer limits frequently.
- Average values for copper, lead and zinc in pressure-washing wastewater at boatyards were determined to be 55, 1.7, and 6.0 parts per million, respectively. For shipyards, those values were determined to be 12.5, 0.34, and 6.6 parts per million, respectively.
- Eighty to 90 percent of the heavy metals copper, lead, and zinc is contained in the suspended solids fraction of pressure-washing wastewater.
- The greatest percentage of wastewater suspended solids is less than 50 microns, or two thousandths of an inch, in diameter. These small particles resist rapid settling and tend to plug surface filters, such as cartridge and bag filters.
- Oil and grease and regulated organic compounds were not determined to be problem contaminants in pressure-washing wastewater. These contaminants, however, could become a problem if spilled or leaked to the area where pressure-washing takes place.

Wastewater Treatment

- Treatment for the removal of suspended solids in pressure-washing wastewater lowers the concentration of copper, lead and zinc to acceptable levels for discharge to sanitary sewers.
- Treatment for the removal of dissolved metals is required to lower the concentration of copper, lead and zinc to NPDES limits for discharges to receiving waters. Treatment methods or systems designed to remove dissolved metals were not tested. Possible treatment methods for removal of dissolved metals are reverse osmosis, ion exchange or distillation.
- For two wastewater samples analyzed, settling retention required more than eight hours to settle enough wastewater suspended solids to come close to meeting sewer discharge limits. Ordinary physical settling by itself, therefore, is not an effective method for producing treated effluent that will meet sanitary sewer limits consistently. Enhanced physical settling systems using settling plates or tubes were not tested as stand-alone systems.

Pilot-testing

- Of the 11 wastewater treatment systems tested, all were determined to be capable of treating wastewater to levels below Metro and boatyard NPDES sanitary sewer limits. Five systems used filtration and six systems used chemical flocculation as the main treatment process.
- Except for ultrafiltration, filtration processes require settling or chemical coagulation of wastewater solids before filtration to avoid excessive filter maintenance.
- No tested treatment system was determined to be capable of treating wastewater to levels below the NPDES receiving water limits for boatyards or shipyards.
- Chemical batch treatment using a coagulant such as alum was determined to be the most

adaptable and cost-effective treatment method for small boatyards using 75 gallons of water or less per wash. Chemical and filtration systems operating either as batch or as continuous treatment are effective for larger boatyards and shipyards. To avoid the need for high-volume treatment and holding tanks, large shipyards generating up to 15,000 gallons per day are advised to use a treatment system that operates in a continuous mode.

- Bilge water poses a difficult problem for effective, consistent treatment. The treatability of bilge water to remove oil and grease is dependent on the type of materials released to the bilge or used to clean the bilge. Effective treatment by oil/water separation alone can only be successful if emulsifying chemicals are kept from entering the bilge. Bilge water may require several stages of treatment and may not be practical on-site at all if bilge water is regularly emulsified or contaminated with regulated organics.

Recommendations

Wastewater Treatment Implementation

- Implementation of the treatment and discharge of pressure-washing wastewater to sanitary sewers is recommended at boatyards and shipyards in the Puget Sound basin. This implementation is considered as an attainable and cost-effective plan that will significantly reduce current contaminant discharges to state waters from these sources. The plan is consistent with the goals of Ecology's NPDES permit program for boatyards and shipyards. It seeks to protect those aquatic environments near maritime facilities that are most susceptible to adverse environmental impact.

Discharge Options

- Discharge to municipal sanitary sewers is recommended as the most achievable, cost-effective and appropriate route for pressure-washing wastewater.
- The option to achieve zero-discharge of pressure-washing wastewater by using closed-loop recycling or evaporation may be achievable at maritime facilities. The treatment systems required for recycling and evaporation are available but require field-testing to confirm their feasibility. At present time, boatyard facilities generating smaller volumes of wastewater are probably better candidates for zero-discharge options than shipyards. It is recommended that Ecology and sewer agencies track and publicize the performance of recycling systems that are operating and, where possible, support field tests of recycling systems through funding and organizational efforts.

Solids-handling

- Finding a clear best option for boatyards and shipyards to dispose of their pressure-washing treatment sludge is problematic. Categorizing treatment sludge as hazardous or not hazardous is dependent on the TCLP test and perhaps on a bioassay test as well. Two sludge samples analyzed during the project passed TCLP tests. Whether other sludge samples will pass the TCLP test and whether Ecology will require a bioassay test in the future is uncertain. Given the small quantity of sludge produced at maritime facilities, particularly boatyards, it is recommended that maritime facilities regard their treatment solids as hazardous waste. This approach will reduce the liability associated with waste disposal. The cost of disposing of the sludge as hazardous waste may offset the risk of disposing of the sludge at a municipal landfill.

Best Management Practices

- Best management practices (BMPs) are recommended as the most appropriate and cost-effective ways to reduce nonpoint pollutant discharges from boatyards and shipyards. Ecology's boatyard NPDES permit will require the implementation of BMPs at boatyards.

- Contamination of stormwater runoff at boatyards can be largely attributed to inadequate source-control efforts. Better pollution prevention, housekeeping and materials storage practices at boatyards will undoubtedly result in reduced pollutant discharges. The importance of using BMPs cannot be underestimated. BMPs can be far more cost-effective than treating large volumes of wastewater for low levels of contaminants.

New Construction

- It is recommended that new maritime repair facilities be required to install wastewater collection systems at all pressure-washing locations. Collection systems would include water impervious surfaces, perimeter containment berms, a sump or sumps, and provisions for pumping wastewater to a treatment system. A wastewater treatment system that would comply with NPDES and sanitary sewer permit engineering specifications could be installed later.
- It is recommended that all new facilities be required to construct paved surfaces wherever boat repair work is to be done.
- It is recommended that installation of storm drains and catch basins be required at all new facilities.
- New facilities should be informed of the advantages of totally enclosing any operation that produces contaminated dusts or aerosols. Compliance to regulations governing air pollution, stormwater and best management practices is greatly facilitated by totally enclosing pollutant-generating activities.

Research and Development

- It is recommended that a continued effort be placed on research and development in the following areas:
- Recycling wastewater treatment systems
- New formulations for bottom paints that are less toxic or nontoxic
- Practical portable and permanent work enclosures for boatyards.

Education

- It is recommended that public agencies including EPA, Ecology and Metro continue to use education as a primary method for encouraging the maritime industry to implement and comply with existing and future environmental regulations. During the course of this project, it was observed that many maritime businesses have a commitment to environmental protection but lack information about or experience with environmental regulations. Education, which clearly explains regulations and offers practical solutions and options, can greatly improve cooperation between agencies and maritime businesses and, in turn, secure a greater degree of pollution control and permit compliance. Education can also help encourage businesses to be self-motivated in implementing pollution control management practices and incorporating treatment hardware into their facilities.

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